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Part 1.—Rice Blast and a New Smut on the Rice Plant.

A. F. ANDERSON

Part 2.—Preliminary Report on Treatment for Rice Smut.

E. WALKER.

Address all communications to

S. C. Experiment Station, Clemson College, S. C.
Freight and Express Office: Calhoun, S. C.
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Rice Blast and a New Smut on the Rice Plant.

ALEXANDER P. ANDERSON.

INTROUCTORY.

It would be unnecessary to say anything about the importance of investigating and trying to find remedies for any diseases that affect our daily food crops. Rice, as is well known, forms one of the principal foods of the human race. It is cultivated in all the continents of the globe, but our own State leads the world in producing the finest quality of rice—the South Carolina rice of commerce.

In the United States rice has few diseases when compared with the rice of other countries. In Italy a disease known as "Brusone" often destroys the entire crop and no satisfactory remedy is, as yet, known. It is known, however, to be due to a fungous disease. Fortunately, "Brusone," as far as we know, is not found in America. Other diseases, and some of them very destructive, are known to exist, but they have, as yet, received very little attention. This, no doubt, is due to the fact that rice culture is so different from that of any other agricultural crop, requiring a thorough knowledge of the methods of growth of the rice plant, its physiology, its soil requirements, drainage and cultivation. The successful rice planter never attempts to grow rice for profit before he knows all there is to know about the cultivation of the rice plant, together with a vast amount of knowledge, acquired only by experience.

It is not our aim in this bulletin to give any ideas on rice culture, but only to give the results of some preliminary investigations on a rice smut, and some observations of leading planters, on the "rice blast," hoping that we may be able to continue this work with the aid and co-operation of the rice planters themselves and also that other stations will follow and add to our present scant literature on rice diseases and their treatment.*

*The insects affecting the rice plant have been worked up, and an account of these are given in the report of the Commissioner of Agriculture, Washington, 1881–1882. Report of the Entomologist. Insects affecting the Rice Plant.

RICE BLAST OR BLIGHT.

During the past three years many letters have been received from prominent planters, enquiring about the causes of the rice "blast" and its treatment. We are sorry to say that we have not been able to answer these inquiries with any satisfaction, but we feel the need of more investigation and work on this disease which should be done in the rice fields at the time of the growing season.

Blast or blight, as the name indicates, is a premature or sudden death of the rice plant or at times only the heads. It is due, no doubt, to one or more causes, or rather there is more than one kind of rice blast, each one due to a different cause.

In the annual report of the United States Department of Agriculture, 1881 and 1882, Col. John Screven, one of the leading rice planters of South Carolina, gives some of his observations on the blast. He finds that when only one to seven of the heads of rice in a patch of rice 150 feet square, have a dead, white or "blasted" appearance, the cause is without a doubt due to the rice stalk borer. Where the injury, however, is widespread, and when many heads are affected the presence of the "white blast," may be suspected. At first this white blast was thought to be due to the presence of deleterious elements in the soil and the soil was said to be "poisoned." This could not be the cause, nor could the "brackish water" theory be the cause, since the rice in the same field, and also in two fields with equally brackish water, one of them might be badly affected and the other hardly at all. Col. Screven observed also, that the white blast appeared after the "harvest flow" had lain on the soil for about forty days and that the first heads that shot out were affected. The later heads were generally free from the blast. The leaves and stalks of the affected plants remain green and the heads eventually turn black.

Blast attacks upland as well as lowland rice, and to a damaging extent, as the following from Senator L. S. Connor shows:

"Middlepen, S. C.

"Fifteen or twenty years ago upland rice was a profitable crop in this part of the State, but for the last few years it is one of the most uncertain crops that we can plant. Even when the seasons and other conditions seem to be perfect, yet the crop will blast from some cause. While apparently the heads are all right, yet when

taken to the mill, the grain goes to flour. * * The last season I have seen and heard less of it than for several years. There is no indication of smut, but the grains seem to ripen prematurely, or, rather, fail to fill out, even when the stalks and blades seem to be very healthy and vigorous. I would suggest the best way to study this subject would be to visit the fields next season and investigate in the fields." * *

Mr. John C. Porcher, of Oakley, S. C., has kindly furnished me with the following description of blast in rice on the Cooper river:

"I class this disease under two heads, direct and indirect blast, and describe them as follows: 'Direct blast' is when the head shoots out dead; there is no semblance of life and the planter recognizes at once, or in a few days, that it is a dead head.

" 'Indirect blast' is a most subtle disease and is not detected until you suddenly see that your rice is off in the color of the grain, instead of being of a bright, gold color, as gold rice is, or a fine white, if white rice. You suddenly and without warning find your crop has assumed a dark tan appearance. A closer examination discloses the fact that your crop it dead—and has died without any sign, outwardly, of disease. Some of the grains are fully matured, but the majority are dead milk, and as a crop it is a loss.

The writer has suffered at different times, greatly, from this disease, but was unable to determine in his own mind, positively, what the disease was, or that there was any cure for it, until this season. One reason for this inability to locate the disease and its cause was that the plant presented in itself no sign of anything wrong, but is absolutely healthy and luxuriant in appearance, and deceives you until it is too late to do anything but accept your loss with the best grace possible.

"Finding this season that my earliest rice, which was looking most luxuriant, was blasted, I began to pull up the plants and examine them thoroughly. I found in every case that the roots were black and lifeless, those with a direct blast being perfectly dead, and those indirectly blasted having slowly but surely lost all vitality until at the end there were no roots left to sustain the life of the plant. I discovered maggots, but was not satisfied that they were in sufficient numbers to do so much damage, but I was satisfied that it was a water disease, because I found that on the higher lands and

edges of my blasted fields the rice was much better, and had not suffered as the rice directly in water. I determined to drain my later rice at once, and to keep it dry. The advanced heads of this rice were blasting. The effect of drainage was instantaneous. As soon as the water left the land, the diseased milk took on life and matured and the roots got healthy. It has been claimed by the United States Department of Agriculture at Washington that the cause of the blast in rice from a fungous growth in the tube of the plant. I dispute this proposition and claim that any one living with his rice, can recognize and trace the formation of this growth which comes to the plant because of its disease at its roots and is only completed in its formation when the plant gives up its last life and is formed, so to speak, from the tissue of the plant, dead.

"I believe that one cause of our being unable to overcome the disease is because we are in the habit of looking at the leaf of our plant for disease, and in this disease the leaf is perfectly healthy. I attribute this to the fact that the plant at this stage requires all of its vitality to shoot the head and is unable to throw off in this struggle to perform its functions all appearance of disease, thus deceiving us until it is too late to save ourselves. I lay down myself this rule for the future: Examine continually the plant and its roots, always taking the plants from the lower sections of the field, and always remembering that a diseased root means a diseased plant, and a diseased head will surely follow."

The above description shows us at least one cause and remedy for the blast. The indirect blast was remedied by Mr. Porcher by drawing off the water just at the time when the roots were apparently suffering from an insufficient amount of air. The roots of the rice plant, although it grows in water, and moist soil, must have air from the time it germinates until it matures. Water always contains air dissolved in it, usually enough to supply the roots. Should this air be extracted suddenly by other water plants and microscopic animals, maggots, etc., the rice plants might suffer and the roots are suffocated and die. As soon as dead it is only a question of a few days before the whole rice plant dries up prematurely.

The indirect blast from the observations of Mr. Porcher appears to be caused by some defect in the root system due to defective drainage or aeration of the roots. The direct blast from all accounts

appears to be due to a fungus which requires further study. On specimens received several times, from Mr. John B. Gregorie, Yemassee, S. C., a species of "Cercosporo" was found on the leaves and stems. But the fact that the first heads shoot out dead, leads us to believe that it is caused by one of the loose smuts. It is to be hoped that the rice blast may be worked up in the near future.

RICE SMUT.

In December, 1898, we received from Mr. Reid Whitford, United States Engineer, Georgetown, S. C., a few rice plants which were affected with a smut. Samples of flour from normal and smutted rice were also sent us. The flour made from the smutted rice was much darker in its color than the normal, and when examined with the microscope was found to contain numerous large, black spores, the cause of the dark coloration. In Fig. 2 A the black spores are shown at a, mixed with the starch and gluten grains. The smutted heads and flour was taken from a field of 250 acres on the Sampit river. Engineer Whitford writes that other planters on the same river had fields affected in the same way, and parts of his own were injured to a damaging extent, many heads containing 25 per cent. of smutted grains.

As this was the first time that any smut had been reported on the rice plant in the United States, work was immediately begun and since then we have been able to find the cause and are able also to suggest a probable remedy for this new and dangerous enemy of the rice plant.

CAUSE OF THE DISEASE.

The disease is caused by one of the fungi, known as smuts. The smuts are microscopic plants which live on the inside of the hosts or plants on which they grow. Many of the smuts are familiar to every one. The stinking smut of wheat and corn smut are good examples. The smuts resemble each other in their life history and mode of infecting the plant or host on which they live. The infection usually takes place in the young seedling, as soon as the seed germinates. The black spores of the fungus are mixed with the wheat or other grain in the threshing and germinates at the same time as the seed when it is sown. They are thus ready to infect the plant at the time of the germination of the seed. After the smut has

once succeeded in getting inside of the plant, it grows upward in the tissues of the stem, and at the time of flowering, infects the seed in its milky stage. The grain or ovary instead of maturing is totally destroyed and converted into the well-known black mass of spores, which are able to remain in a dormant condition over winter and are ready the next spring to renew their attack.

One of these smuts is known as the stinking smut or "Tilletia." The rice smut is a "Tilletia," or stinking smut, and from all appearances, is similar to the stinking smut of wheat, only another species.

Professor F. S. Earle of Auburn, Alabama, has kindly assisted me in identifying the species and found it to be "Tilletia Corona," Scrib. This smut has never been reported on rice before, but has been found on several grasses. It was first described by S. M. Tracy and F. S. Earle, in the Bull. Torr. Club, Vol. 23, page 210, 1896, and also in Bull, No. 36, of the Mississippi Agricultural Experiment Station, May, 1896.

The following on this smut we copy from the original description by S. M. Tracy and F. S. Earle:

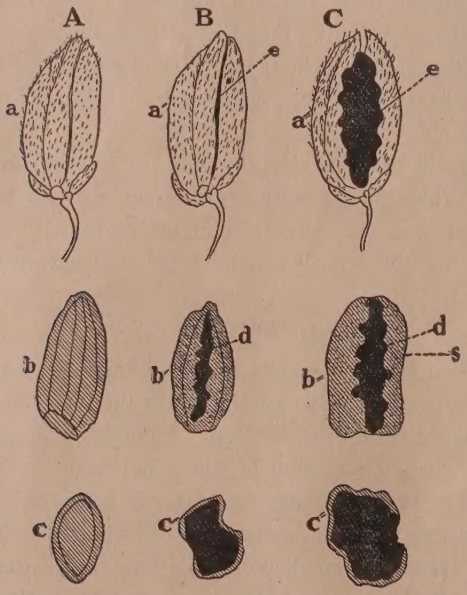

FIG. 1.—A. B. and C.—Three grains or spikelets of rice; a, normal, mature spikelet or grain; a', one with the two husks or glumes partly pressed apart, showing the black spores within; a'', one that has been more completely destroyed. The whole ovary or seed has been converted into a mass of spores; b, a normal rice grain with the husk removed; b', a smutted rice grain with the husk removed. The fissure at d, shows the black spore mass; b'', one that has been more completely destroyed; s, the ovary wall or skin covering the spore mass within; c, c', and c'' are cross sections of one normal, and two diseased, rice grains.—(Original.)

"This stinking smut was first observed by Scribner on "Homalocenchrus oryzoides" and "H. Virginicus" near Washington, D. C., in 1886, and specimens collected by him were distributed by Ellis under the above name in N. A. F., as No. 1896. It has since been collected by Waite in Illinois and Missouri on "Momaloccenchrus," on "Panicum Virgatum" in Illinois, and by the writers in Mississippi on "Homalocenchrus lenticularis" and "H. Virginicus" at Columbus, on "H. lenticularis" at Bairds, and on "Panicum sanguinale" at Starkville. Specimens on "Panicum virgatum" in the Herbarium of the Division of Vegetable Pathology at Washington bear the unpublished herbarium name "T. pulcherrima" Ell. and Gal., but they seem identical with the forms on the other hosts. As no description of this species has been published, we make the following drawn from an examination of all the above mentioned material.

TILLETIA CORONA SCRIB.

Infesting the ovaries, transforming them into black, curved, horn-shaped masses, sometimes 1 cm. in length, the outer covering firm in texture, showing traces of the cellular structure of the ovary; spores large, spherical, 22-26 *u*, dark, fuscous and densely opake when mature, but covered with a hyaline envelope 2 *u* or more in thickness; the surface of the dark central mass covered by minute but deep alveolations, this structure being obscured by the opacity of the mature spore, when the thin alveolar walls can be seen only at the periphery, where they appear like numerous spinous projections reaching almost through the hyaline envelope. The remains of the fruiting hypha often persist on the younger spores as a false pedicel.

On various grasses, Mississippi, Illinois, Missouri and Washington, D. C.

Several other species of "Tilletia" have similar large spores with a hyaline outer covering, but in the others the spores are less dark and opake, and the alveolar reticulations are much larger and more easily recognized. These species form a natural group quite distinct from the other "Tilletias," and might well be considered as constituting a distinct genus."

It will be seen from the above description that this smut has never been reported on the rice plant. It affects the rice plant somewhat differently from what it does its other hosts. The diseased ovaries, or grains, are seldom abnormally increased in size, nor do they become curved and protrude out of the glumes, but remain

inside of the glumes, seldom pressing them apart. Very often smutted and normal grains are so much alike that the one is often mistaken for the other. In Fig. 1 are shown three spikelets, the one at a normal; a', diseased, and a'', one that is badly smutted, exposing the black spore-mass within.

The grains or ovaries are usually totally destroyed, having been converted into a mass of black spores. The spores are large for smut spores, being about one-thousandths of an inch in diameter. They are covered over with a hyaline envelope and numerous spine-like projections. (Fig. 2 B, f).

Mixed with the spores are also numerous immature spores that have been arrested in their growth, also remains of the fungus mycelium (Fig. 2, B, g, m.)

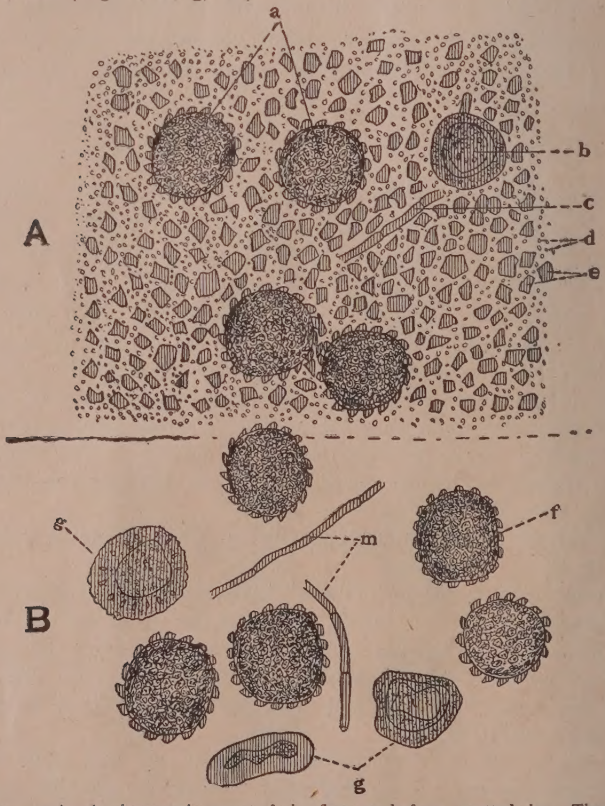

FIG. 2.—A.—A microscopic mount of rice flour made from smutted rice. The black smut spores at a, are mixed with the flour, giving to it a dark color; b, an immature smut spore; c, a piece of the smut fungus mycelium; d, gluten grains; e, grains of rice starch. B.—A mount made from a smutted rice grain; f, smut spores; g, immature smut spores; m, remains of the smut fungus mycelium. All highly magnified.—(Original.)

MODE OF INFECTION.

To determine the probable mode of infection of the rice plant, cross sections of the rice stems or straw, were made to see whether the smut mycelium was present in the stems. Cross sections of several stems, with smutted grains, were made and the mycelium found. The mycelium is found only in the vertical rows of chlorophyll parenchyma that are found in between the rows of fibrous, strengthening tissue in the stems.

In Fig. 3A, b, and Bf, are shown cross sections of the leaf green areas of the stem, with the fungus mycelium at m. This fungus mycelium grows upwards in the straw until it reaches the grain. In Fig. 4 is shown a longitudinal section of the rachis about one-fourth of an inch below a smutted grain. The mycelium is shown at m.

The presence of this mycelium in the straw proves, no doubt, that the infection takes place through the rice seed and the black spores that are mixed with the grain in the threshing are the ones that infect the young rice seedlings as soon the seed germinates. After the infection, the mycelium of the fungus grows upwards in the rice stem as it increases in length, finally attacking the grains and destroying them, and converting them into a black mass of spores. Remains of the smut mycelium are also found in the destroyed ovaries. The mycelium found in the ovaries is identically the same as the one found in the cross and longitudinal sections of the rice culms.

ORIGIN OF THE RICE SMUT IN SOUTH CAROLINA.

As stated above, "Tilletia corona," Scrib., has been found on various grasses in Mississippi, Illinois, Missouri and Washington, D. C., but has not been reported on these grasses in this State.

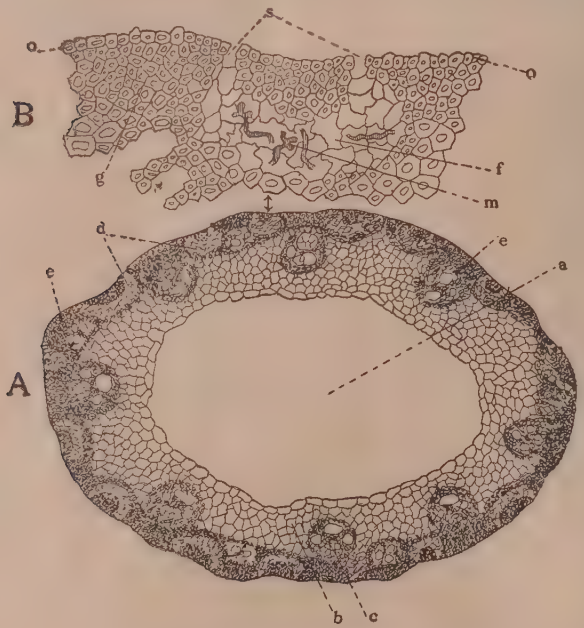

FIG. 3.—A.—Cross section of a rice straw about eight inces below the panicle or head; a, the hollow interior of the straw; b, colorless parenchyma tissue, next to the cavity; c, a bundle with large pores, through which the sap passes; d, areas of chlorophyll or leaf-green parenchyma cells. The smut fungus is found in these; e, stereome or strengthening tissue of the rice straw. B.—More highly magnified portion of one of the leaf-green areas of the straw at d; f, leaf-green parenchyma cells; g, stereome or fibrous strengthening tissue; m, threads of the smut mycelium; o, the epidermis or outer skin of the rice stem, with two breathing pores at s. All highly magnified. (Original.)

In Japan a "Tilletia" has been found on the cultivated rice plant, viz: "Tilletia horrida, Tak., described as follows: Tokyo Botanical Magazine. 10: 20, 1896.

"'Tilletia horrida,' Tak.—Spore masses pulverulent, black, produced within the ovary and remaining covered by the glumes. Spores globose, irregularly rounded, or sometimes broad-elliptical, the round ones 18.5-23.0 *u* in diameter and the elongated 22.5-26.0 x;18.0-22.0 *u* in size. Epispore deep olive brown, opaque, thickly covered with conspicuous spines. The spines hyaline or slightly colored, pointed at the apex, irregularly polygonal at the

base, more or less curved 2.5-4.0 *u* in height, and 1.5-2 *u* apart at their free ends. Sporidia filiform or needle-shaped, curved in various ways, 10-20 in number and 38-53 *u* in length. Hab. On "Oryza sativa" L. From Tokyo and Kyoto."

By comparing the above description of "Tilletia horrida," Tak., with that of "Tilletia corona," Scrib., it will be seen that the two agree and are apparently identical. In that case, it is possible that the Japan rice smut has been introduced into South Carolina. In answer to a letter of inquiry as to whether any rice seed from Japan has been introduced at Georgetown, S. C., Engineer Whitford kindly sent me the following:

"Dear Sir: Replying to your letter of February 28th, I have been informed that year before last two sacks of Japanese seed rice were sent here by the Clyde Steamship Co. The experiment of

FIG. 4.—A longitudinal section of the rachis, or part of a rice straw about one fourth of an inch below a smutted grain; a, the epidermis or outer skin of the straw; e, chlorophyll parenchyma tissue with threads of the smut fungus mycelium at m; s, fibers of strengthening tissue. All highly magnified. (Original).

planting it was tried by two planters. They were not successful, and no further attempt was made to introduce this seed.

"Yours very truly,

"Reid Whitford."

No matter what the origin of this smut, it is here and must be dealt with and investigated until proper treatments are found.

TREATMENT.

The presence of the fungus mycelium in the rice culms probably indicates that the infection takes place in a similar way to that of the stinking smut of wheat, oat smut, etc. In that case, a treatment similar to the hot water, copper sulphide and other treatments for oats and wheat smuts could also be used in the treatment for rice smut.

No records are available showing that rice seed has ever been treated with these fungicides, or treatments. Before we can suggest any of the above treatments for the rice smut, it is necessary to know whether rice seed can be treated with any one of these treatments, without injuring or killing it, as well as the smut spores found mixed with the seed.

Wishing to hasten the publication of this bulletin and to suggest, if possible, a treatment for the rice smut, Mr. Ernest Walker has kindly assisted me in treating and germinating the rice seed. The results of his experiments are given in the second part of this bulletin.

I am indebted to Mr. Reid Whitford, United States Engineer, Georgetown, S. C., for supplying me with material. To Dr. A. C. True of Washington, Professor F. S. Earle of Auburn, Alabama, Director William Trelease and Mr. J. B. S. Norton of the Missouri Botanical Garden, St. Louis, for kindly supplying me with references.

PART II.

A Preliminary Report Upon Treatment for Rice Smut.

(Ernest Walker.)

INTRODUCTORY.

A brief account of the grain smuts and the methods of treatment was given in Bulletin 36, recently published by this station. It may be desirable, however, to again review their characters here. Smuts are minute parasitic plants of a low degree of organization. The plant body is totally unlike that of ordinary, green plants, and consists of delicate light-colored, cobweb-like threads, living in the tissues of the plant attacked.

In the tissues they live concealed and attract no attention—except possibly by their dwarfing effect upon the host—until they have arrived at the reproductive stage, which is commonly simultaneous with that of the plant in which they are living. At this time, they produce vast numbers of minute reproductive bodies, or spores, usually within the seeds or ovaries of the host plant, converting the interior of the seeds into a mass of sooty, black spores. A single diseased kernal will contain many thousands of these minute spores, or enough, doubtless, if well scattered to contaminate the seed for an acre.

Being small, this wide dissemination readily occurs. Winds may blow the spores about, but the most effective distribution takes place at the time of threshing, as in the case of wheat smut. At this time many of the diseased grains which are mere shells are broken, and their contents set free among the good seeds. Minute spines or hooks on the spore, and sometimes the roughness or pubescense of grain assist the spores to cling to the surface of the seed with which they come in contact.

If, after threshing wheat from fields where smut has existed, even to a limited extent, the grains are placed under a strong miscroscope and examined, many, or most of them will be found to have one or more smut spores clinging to their surface. Sometimes the spores clinging to a grain are so numerous as to form a "smutty patch."

In the case of smuts, infection does not occur in the field—that is, by the disease spreading from one growing plant to another. This occurs at the time of germination. The presence of these minute spores on grain seed, therefore, is full of significance.

Ordinarily the conditions favoring germination of the grain, favor the germination of the spores of the parasite, and it is at this time its thread-lke body gains a ready entrance into the delicate tissues of the host. The two plants then grow on together until the fruiting stage, when the smutted grain reveals again the presence of the parasite.

Smut diseases of grains have been known and a source of great annual losses since the days of Greece and Rome. For a long time the great damages they and other like diseases wrought to crops were regarded as necessarily occurring and beyond human control, or as special manifestations of Divine disfavor. The nature of the trouble was not suspected. We now know, however, that these diseases are due to a specific cause and understand the nature and life habit of the organism directly responsible; and, furthermore, during the past eleven or twelve years, remedies have been found which if put into universal practice would well nigh banish such scourges from our grain fields.

It is to be hoped that farmers generally will turn their attention to such matters. The case is emphatically one of unproductive consumption. The stinking smut of wheat alone ("Tilletia foetans") in some districts of the south occasions an annual loss of from 50 to 75 per cent. of the crop. The loose smut of oats from 6.5 to 15 per cent. According to figures of the United States Department of Agriculture, the loss to the whole country from the loose smut of oats ("Ustilago avenae") amounts annually to some $18,000,000.

Not only could this large loss be saved by the proper treatment of seeds, but by the simple operation, in the case of some of the treatments, a considerable extra increase in the crop may be secured, practically doubling or trebling the amount saved by the treatment. Considering the figures above, this, for the country at large, would amount to a large sum indeed.

RICE SMUT.

This smut an account of which has already been given in the preceding pages of this bulletin, affects rice grains in a manner similar to that in which the stinking smut affects wheat.

So far it has been found in but one locality in South Carolina and seems not to have become sufficiently abundant to occasion any large percentage of loss. If, however, the rice crop in the South Atlantic States should become generally affected to the extent represented in the sample (1) we have examined, the loss, according to figures of the census of 1890 would amount to some $40,000.

If it should become abundant in rice fields it is capable of causing even greater losses than represented in the figures mentioned. Rice being a large crop in this State, it is important that some remedy be found which will give growers a means of controlling the disease should it tend to become generally troublesome.

The following are some preliminary observations and suggestions relating to treatment:

EXAMINATION OF SMUTTED RICE SEED.

The small sample of seed at hand on examination showed (out of 1,500 seeds) 7.5 per cent. of poor, or light but unsmutted seeds; and of smutted grains 3.7 per cent. All the seeds had smut spores in greater or less number adhering to the husks. It is probable that the percentage would on more extended examination be found higher than this, possibly 5 per cent., for the single locality in which the smut is known to exist.

The figures above were obtained by separating the good and bad seed in water. The seeds were placed in a vessel of water; the heavy seeds sank; the smutted, light or imperfect floated, and were skimmed off.

On placing the seeds in water and stirring them about, all really good seeds sank after a few seconds. The roughness of the husks and their dryness prevent their being moistened immediately. Bubbles or a film of air among the minute spines at first cause many of the seeds, both good and bad, to float. Those seeds which float after the outer coat is moistened contain air spaces on the interior.

1. The samples of smutted rice came from Georgetown, S. C., in September, 1898, and were kindly furnished by Mr. Reid Whitford, United States Engineer.

After the separation by the above method a careful examination was made of both lots. The heavy seeds were examined as well as the light and were found to be uniformly good. Subsequent germinations confirmed this examination—the germination of good seeds after the water separation being in eight different lots 100 per cent.

An examination of the light seeds showed these were uniformly defective, or diseased. Some contained kernels which were greenish or immature, and small, leaving the husk unfilled. Some of these would germinate, no doubt, but such seed do not, as is well known, produce strong plants. Other husks were empty and flat. The balance were filled with smut spores. The latter do not appear noticeably different from healthy seeds, and it is difficult or almost impossible to pick them out merely by their appearance, although after some practice the eye can detect them fairly well by a slight difference in color, or duller appearance. In the above examination, however, each light seed was opened.

While there is a comparatively small percentage of the seeds filled with smut spores, the presence of this small number is sufficient to account for the contamination of the healthy seeds. Each smutted kernel contains thousands of spores—probably enough in each kernel, if well disseminated, as was previously remarked, to contaminate the seed rice of an acre.

While smut spores may be scattered by winds during the summer, it is probable that the most effective scattering occurs at the time of threshing, when some of the smutted grains, which are mere shells, are broken, and their contents scattered among and on the good seeds. The presence of smut spores on all the seeds, therefore, it is likely, is brought about in this way. In the case of steam threshers, some spores remain in the machine, and in this way a thresher could spread the disease from plantation to plantation.

GERMINATION OF THE SPORES.

An effort was made to germinate spores of the smut, and determine the effectiveness of several fungicidal substances in killing them. Different lots were treated with potassium sulphide, formalin, copper sulphate; some were scalded and others were untreated. No spores, however, germinated. An effort by the botanist to germinate the spores was also unsuccessful.

None of the dishes used by the writer were sterilized, the object being to see which fungicide would best accomplish this while killing the spores. The vessels were kept some weeks. Potassium sulphide and copper sulphate, of 1 and 1-2 per cent., respectively, effectively sterilized the germination vessels, in which they were used. Among spores in the other vessels after a time various fungi and bacteria were found.

THE EFFECT OF SOME FUNGICIDAL TREATMENTS UPON THE GERMINATION OF RICE.

The principal object of this germination test was to see what effect soaking the seeds in a few of the well known fungicidal solutions would have upon germination. The test was only a preliminary one, and entered upon unexpectedly.

Two series of vessels containing seeds for germination were arranged. Series 1 consisted of rice free from smut. Series 2 of rice affected with smut. The first was merely a duplicate check series. There were five vessels in each. In every case smutted and light seeds were floated out, and only the good seeds were used. The vessels of each series receiving the same treatment were given the same number.

Except in the case of scalded seeds those used in each treatment were allowed to stand in the solution 24 hours. Those scalded were subsequently soaked in cold water 24 hours. The following memoranda show the treatments given the separate lots in each series. During germination the seeds received an average temperature of 24 C (75.2 F.)

The following is a memorandum of the treatments given the several lots of seeds.

1. Soaked 24 hours in a 1-2 per cent. solution of copper sulphate. (No subsequent treatment with lime water.)

2. Soaked 24 hours in a 1 per cent. solution of potassium sulphide.

3. Soaked 24 hours in a 1-2 per cent. solution of concentrated bromine water.

4 Soaked 24 hours in a 1-2 per cent. solution of formalin (40 per cent. solution of formaldehyde.)

5. Scalded three seconds in boiling water, then soaked 24 hours in cold water.

In addition to the parallel series the following two separate lots were treated at the same time.

6. Soaked 24 hours in cold water.

7. Soaked 24 hours in a 1 per cent. solution of pyoktanin.

After soaking the seeds 24 hours, the solutions were poured off and the seeds rinsed. This soaking was sufficient to moisten the husks through, and slightly soften the kernels.

The copper sulphate had a faint bleaching effect upon the husks, and colored the white kernels a faint greenish tint. The salt, however, did not color deeper than the true seed-coats.

The solution of potassium sulphide gave the husks a deeper yellowish hue.

The bromine and formalin changed the husks slightly darker.

Pyoktanin stained the basal bractlets deep purple, the husks slightly but not uniformly, and the kernel only when there was some opening through the husks, and then it did not penetrate through the seed coats.

INFLUENCE OF TREATMENT UPON GERMINATION.

The several lots of seeds after treatment were placed in an incubator on January 30th at 5 p. m.

On February 1st, after 40 hours, all lots began germinating about equally. A slightly more vigorous and more advanced germination, however, was noticeable in the seeds which had been soaked in bromine water.

On the following day this gain was even more pronounced—the rootlets of bromine-treated seeds being from 1 to 2 centimeters long, while those of other seeds were only from .1 to .8 of a centimeter in length. The germination moreover of these seeds was noticeably more vigorous.

Seeds treated with copper sulphate showed in the third day following germination a noticeable irregularity. All were growing, but growth was unequal and behind the other lots, excepting the pyoktanin-treated seeds in which, while some were vigorous, others were small, the lot exhibiting considerable irregularity in growth and height.

In all lots the percentage of germination was 100, showing the result of separating out the poor seeds by floating as previously described.

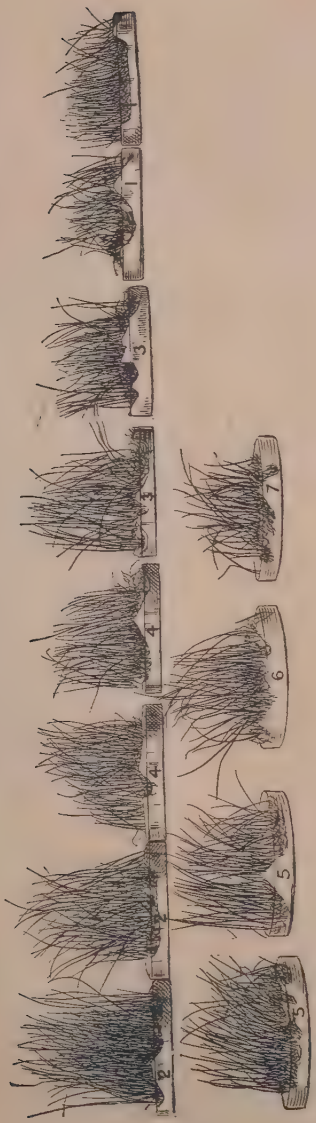

FIG. 5.—Rice seedlings from seed previously treated for the destruction of smut spores; 2.2., seeds soaked 24 hours in 1 per cent. solution of potassium sulphide; 4.4., soaked same time in 1-2 per cent. solution of formalin; 3.3., soaked same time in 1-2 per cent. solution of concentrated bromine water; 1.1., soaked 24 hours in 1-2 per cent. solution of copper sulphate; 5.5., scalded 3 seconds, then soaked 24 hours in cold water; 6, no treatment, soaked 24 hours in cold water; 7, soaked 24 hours in .1 per cent. solution of pyoktanin.

On February 5th the bromine-treated seeds were still ahead in one series, but were falling behind in the other (smutted rice). The bromine-treated seeds in both lots from this date began to fall behind what they at first promised, though still keeping ahead of seeds treated with copper sulphate and pyoktanin.

On February 11th the seedling were photographed. This photograph is here reproduced, and shows the relative vigor and growth at this date. (See Fig. 5.) Here it will be seen that in point of size and vigor seeds treated with potassium sulphide (No. 2.2.) are much ahead of all the others, averaging 4 inches in height; growth, moreover, was strong and uniform.

In height and general vigor next in their order were scalded seeds (Nos. 5.5.), formalin; (Nos. 4.4), bromine; (Nos. 3.3.), cold water; (No. 6), and last, copper sulphate and pyoktanin. Between the numbers 5.5., 4.4., 3.3. and 6 the difference in strength of stem was slight. Cold water, however, had slightly the preference, but showed the most irregularity in height.

No smut spores were found germinating in any lot, but other microorganisms developed in some of the dishes and a form attacked the seedlings of some lots after a time, causing a slight brownish appearance of the sheathing leaves at the base of the stems.

Considering healthfulness of the seedlings and freedom from this rot the lots from seed soaked in potassium sulphide (Nos. 2.2.), and copper sulphate (Nos. 1.1.), came first, being entirely free from any signs of disease. The other lots were more or less affected, formalin least, cold water and pyoktanin next, then scalded seeds and those treated with bromine. The latter were badly affected and more so than scalded seeds.

As far as definite results in finding an effective fungicide for the treatment of smutted rice is concerned this experiment was fruitless, as no smut spores germinated in any instance. The fact, however, that seeds treated with sulphide of potassium and copper sulphate were immune from diseases which attacked the other lots, seems to confirm the well established reputation of these substances as fungicides and indicates that they would probably be as effective in the treatment of rice smut as the smut of other grains if infection occurs in the same way. It seems to show, moreover, that their fungicidal

effect is not merely temporary, but more lasting than that of hot water, which, while it may kill all spores at the time of treatment, may allow disease germs to attack the growing seedlings subsequently, though under ordinary soil conditions this objection would probably not be serious.

The same is probably true of formalin. Here the strength of solution used was 1-2 per cent. According to Bolley and Clouse, a soaking of seed two hours in 1-4 per cent. solution of formalin is sufficient for the treatment of smuts. The result above is probably due to the fact that formalin loses its strength on exposure.

As to the fungicidal effects of bromine nothing definite can be said. Through its affinity for hydrogen, it is indirectly "an oxydizing agent and antiseptic." But being volatile, like formalin, a solution looses its strength after a time. It may have immediate germicidal properties, but if it has, they are not lasting, and seedlings from treated seeds are open to attack by disease subsequently. It appears to hasten germination, but in the end proves to have a weakening effect upon rice seedlings. Experimenters at various times have tried the effects of different chemicals upon the germination of seeds in the hope of finding some method of hastening germination without lowering the vitality of the seeds. While in some instances chemicals have been found which hastened germination, they have usually proved in the end injurious to the seeds, as seems to have been the case here with bromine.

Soaking seeds in cold water gave a vigorous growth, but a less uniform vigor than was visible with seeds treated with the other substances, pyoktanin excepted. In the latter case growth was irregular and slow. A 1-2 per cent. solution of copper sulphate as here used did not injure the germinating power of seeds, or retard germination as compared with other soaked seeds, but had a retarding effect upon subsequent growth.

None of the treatments, bromine excepted, had any effect in hastening or retarding germination in comparison with seeds soaked in pure water. The differences were in growth subsequent to pullulation. This, as has been mentioned, was very striking in the case of seeds soaked in potassium sulphide. This and the other observations concerning the effects upon subsequent growth of soaking

seeds in fungicidal solutions leads me here to mention some results recorded showing—

AN INCREASE IN YIELD AS A RESULT OF TREATMENT IN OTHER GRAINS THAN RICE.

Treatments of seeds for smut have been found by various experimenters not only effective in killing the spores, but in the case of oats and wheat, have been found to have a beneficial effect upon the seeds and crop.

In 1889, Messrs. Kellermann and Swingle in experiments with oats found that as a result of the hot water treatment of seeds, there was an increased yield amounting to more than twice the gain that would result from replacing smutted seeds in adjoining untreated plats with good seed. Subsequent trials confirmed this result. Jensen and Arthur had similar results. Swingle says that on an average the increase in yield in the case of oats is double or treble what would result from suppressing the visible smut. The hot water treatment has given similar increase in the case of wheat and barley.

A large increase in yield has been found to follow the treatment of seed oats with sulphide of potassium; but an increase not quite equal to that resulting from the hot water treatment. According to Professor Kellermann treatment with potassium sulphide has the same effect upon oats and corn.

Treatment with copper sulphate and lime water, with oats and wheat, does not, under average conditions, it appears, increase the yield beyond such as results from replacing smutted with good seeds.

With such results before us there is a double inducement to treat seeds even though the percentage of smut be small.

TREATMENT OF SMUTTED RICE.

Until we have succeeded in germinating the spores of rice smut, and have learned how infection of rice plants takes place it will be impossible to say definitely just what fungicide or treatment will be most effective as a remedy. What seems to be the mycelium of this fungus has been found by the botanist in the tissues of rice culmus. Rice grains are affected in a manner similar to that in which wheat is affected by the stinking smut. Spores are found adhering to the husks of the seed. The smut appears to be closely related to stinking wheat smut. The spores in the seeds may not be the ones through which infection of rice seedlings takes place. This infection may result from spores remaining in the soil. It seems probable, however, that the smutty grains, and the spores on the seeds are instrumental in infection. In this case these spores should be destroyed. There are effective remedies for stinking wheat smut, and it seems probable that the remedies for wheat smut will be found useful here.

We have shown that the potassium sulphide treatment may be safely employed; indeed, that it has a tonic effect upon the seedlings. Likewise, that copper sulphate (1-2 per cent. solution) is safe though not as desirable as the potassium treatment, and that the seed may be scalded three seconds with advantage, and soaked 24 hours in a 1-2 per cent. solution of formalin without material injury, while 1-4 per cent. solution has been found by others sufficient in the treatment of stinking wheat smut. Without positive evidence, we believe that any of these treatments would destroy the spores of rice smut. This we hope to find out. That the reader may try them we give several treatments which have been found effective in the treatment of the above mentioned wheat smut.

Before giving the several fungicidal treatments I wish to call particular attention to the method of separating smutted and other light rice grains from the good and heavier seeds. Not only may a large number of smut spores be destroyed in this way, but the process is attended with another advantage. During recent years experimenters have frequently shown that the largest and heavier seeds of various plants produce the best plants and crops. A marked gain results from selecting such seeds. He who would improve his varieties and crops must practice selection. It is the plant breeders

magic wand. It is not enough that we select out the fittest among plants, but we should carry the principle of selection to the very source—the seeds from which plants spring. By floating out weak and smutted rice seeds, as below described, and using only the heavy and healthy, we will be applying this useful principle to our rice crop.

A METHOD OF SEPARATING SMUTTED, OR POOR, FROM GOOD RICE SEED.

If rice seed in the husk be poured into cold water and stirred about, all good seed sink after a few seconds. Smutted, light or defective grains remain floating. These may then be skimmed off and burned. This treatment answers of course only for rice "paddy," or in the husk.

THE POTASSIUM SULPHIDE TREATMENT.

Dissolve one and a half pounds of potassium sulphide or liver of sulphur (fused) in twenty-five gallons of water in a barrel or other wooden vessel. Add now three bushels of the seed to be treated and stir thoroughly so as to wet every grain. The whole should then be left standing twenty-four hours, when the liquid should be strained off and the grain spread out to dry. This solution may be used over for three lots of seed if used immediately, but the solution of potassium sulphide does not keep. The grain should be spread out to dry in as thin a layer as practicable in order to dry readily. If it is to be sown at once, however, thorough drying will not be necessary.

Some experimenters recommend soaking the seed a shorter time in a stronger solution because the grain is afterward easier to dry. If this method be followed a 2 per cent. solution of potassium sulphide (8 pounds to 50 gallons of water) may be used. In this the grain should be left two hours, and the seed treated otherwise as above.

THE HOT WATER TREATMENT.

Seeds may be immersed for a few seconds in scalding water for the destruction of smut spores, but only for a few seconds, otherwise the embryo will be injured or killed. A safer plan is to immerse them for a longer time in water at a lower temperature. This is the plan which is ordinarily followed.

For this treatment two large vessels holding each some twenty gallons at least are necessary. One of these should contain water at a temperature of 110 degrees to 120 degrees (Fahrenheit); and the other water at a temperature of 132 degrees to 133 degrees, F.

The second vessel should contain as much water as will equal in bulk five or six times that of the seed to be treated. It will then be more easily kept at the proper temperature, which is as near as possible to 133 degrees, F. Besides these vessels two others with a supply of cold and boiling water should be conveniently at hand to be used in maintaining the required temperature of the hot water bath.

The seed to be treated are first placed (a half bushel or more at a time) in a bag of loosely woven material or sacking, or else in a basket of wire netting. Plunge it then first into the vessel containing the water at 110 degrees to 120 degrees. Lift it, and when it has drained a moment plunge it into the vessel with water at 133 degrees. After a moment lift it, allowing most of the water to drain out. Then replunge it, and repeat several times, making sure every grain is wet with the hot water. If the water is maintained at a temperature of 133 degrees the seed may remain in the bath ten minutes, which will kill the spores without injuring the seed. Should the temperature rise to 135 degrees the seed should not be kept in the water over five minutes.

The nearer the temperature is kept to 133 degrees Farhenheit the better will be the results. Below this the spores are not so likely to be killed. Above 135 degrees the seeds may be injured, unless the immersion is very brief. The guaging of temperature should be done with a reliable thermometer. The sack or wire basket should be amply large so that seed while being treated may move about.

If a quantity of seed is to be treated two persons should be on hand, one to handle the grain, the other to maintain the proper temperature of the water, by adding hot or cold water from time to time as may be necessary. That the temperature may be uniform the water should always be stirred whenever hot or cold water is added. If steam is available a small pipe running into the hot water vessel will make it comparatively easy to maintain the proper temperature.

After treatment seed should be spread out on a clean floor in an

airy place in a layer not thicker than three inches, or it may be placed upon sheets resting on a lattice frame a foot or so above the ground. To facilitate drying, grain spread out upon the floor should be shoveled over two or three times a day. If thoroughly dried, seed may be treated some months in advance of sowing. If to be sown immediately they need not be so thoroughly dried.

After treatment care will be needed to avoid reinfection. The seed should not be placed in any vessel or on any surface likely to contain spores of smut, or where smutted grain has been before. Tools or vessels likely to have spores on them may be disinfected by dipping them in scalding water. The floor where the rice is to be spread may be previously disinfected by washing with a strong solution of copper sulphate.

OTHER TREATMENTS.

FORMALIN.

Formalin, (a 40 per cent. solution in water of formaldehyde gas) has been found to be an effective remedy for smuts. It is used at the rate of 1 part to 50 or 60 gallons of water. The seed should be soaked in this solution two hours and otherwise managed as in previous treatments. The dilute solution is not poisonous. The material should be purchased full strength.

COPPER SULPHATE.

Copper sulphate (blue stone) 1 pound in 24 gallons of water is effective as a treatment for smut. The grain should be soaked in this solution 12 hours, after which it should be soaked in lime water for 5 minutes. It should then be drained and dried as in other treatments. The lime water is to be made by slacking 1 pound of lime and then diluting it with water to 10 gallons.

CORROSIVE SUBLIMATE.

This substance (mercuric chloride) while effective as a remedy for smut, is a dangerous poison and must be handled with care. It may be absorbed through wounds on the hands, and grain treated with it is poisonous to animals. It must also not come in contact with metals. In the following treatment a sprinkling-can may be prepared for use in applying the liquid, by thoroughly protecting its

surfaces with lard or axle-grease. A small amount of the grease may be melted in the can, and the parts coated by running the grease about. When cold the holes in the "rose" or sprinkler should be opened with a broom-straw or small pointed stick.

The mercuric chloride is used at the rate of 1 pound to 50 gallons of water. The grain should not be soaked in the solution as in other treatments, but should be piled on a clean floor. The liquid is then applied by sprinkling or as a spray, the grain being shoveled over constantly during the operation, so that every seed becomes moistened over its entire surface. Only enough of the solution should be used to accomplish this end. More is likely to injure the seed.

These treatments do not increase the yield beyond the percentage of smut as in the case of the hot water and potassium sulphide treatments. For this and other reasons they are somewhat less desirable than those treatments.

SUMMARY.

1. A sample of smutted rice from the single locality in South Carolina where it is known to exist showed out of 1,500 seeds 3.7 per cent. of smutted grains, and spores in greater or less number adhering to the husks of all the seeds.
2. If rice in the South Atlantic States should become generally affected with smut to the extent represented in the sample examined the direct annual loss would amount to some $40,000.
3. Rice smut is due to a minute parasitic fungus. It affects rice seed similar to that in which the stinking smut affects wheat, converting the interior of the grains into a mass of black, powdery spores.
4. Efforts to germinate the spores of rice smut were unsuccessful. In consequence, the precise time and method of infection of seedlings remains unknown, nor can definite suggestions as yet be made in regard to treatment.
5. Smutted and light rice seed in the husk can be readily separated from good seeds by floating them out in cold water. The bad seeds float and may be skimmed off and burned. The good seeds sink. By this method many spores can be destroyed.
6. Heavy and plump rice seed separated from smutted and poor

by the method mentioned in paragraph 5 showed in eight different lots 100 per cent. of germination.

7. It is desirable (as is now well known) to use only plump and strong seeds—in other words, to apply the principle of selection to seeds as well as plants where we can. The method referred to above, in paragraph 5, affords an easy method of applying this principle to our rice crop.
8. Except the case of bromine treated seeds, seeds soaked 24 hours in various fungicidal solutions, seeds treated 3 seconds in scalded water and then soaked 24 hours in cold water, and seeds without treatment, but soaked 24 hours in cold water, germinated simultaneously, but showed differences in growth subsequently.
9. In a temperature of 75.2, F., rice seeds, after soaking, germinated in 40 hours.
10. Soaking rice seeds 24 hours in a 1-2 per cent. solution of concentrated bromine water, it seems, hastened germination slightly, but in the end appeared to have an injurious effect upon the seeds.
11. Rice seed soaked 24 hours in cold water all germinated simultaneously with other soaked seeds, but subsequent growth was less uniform than seeds treated with scalding water, or with the several fungicidal solutions, excepting those treated with copper sulphate and pyoktanin.
12. Seeds soaked 24 hours in cold water after treatment 3 seconds in scalding water gave a uniform germination and next to seeds treated with potassium sulphate showed the most growth in a given length of time.
13. A .1 per cent. solution of pyoktanin in which seeds were soaked 24 hours killed no seeds but caused a feeble, irregular growth subsequent to germination.
14. A 1-2 per cent. solution of copper sulphate, without after treatment with lime water, retarded growth subsequent to germination, and caused some irregularity in growth. Seeds so treated next to those mentioned in paragraph 13, making in a given time the smallest growth of any treated seeds.
14. Soaking rice seeds 24 hours in a 1-2 per cent. solution of formalin gave a uniform germination, simultaneously with other soaked seeds. These seeds made third best growth in a given

length of time, potassium sulphide treatment yielding first best results, and scalding next. (See paragraph 12.) This strength of formaline is twice what other experimenters have found to be effective as a remedy for the stinking wheat smut and would no doubt be effective in killing the spores of rice smut.

15. Treatment of rice seeds 24 hours in a 1 per cent. solution of potassium sulphide gave the most uniform and vigorous germination of any treated seeds. The germination was simultaneous with other soaked seeds (omitting bromine.)
16. Potassium sulphide and copper sulphate solutions of 1 and 1-2 per cent., respectively, effectively sterilized germinating vessels in which spores were placed while among the spores which had been treated by scalding, bromine, formaline, salicylic acid and with no treatment, various fungi and bacteria appeared after a time. In the case of seeds also treated with potassium sulphide and copper sulphate seedlings remained healthy while those receiving other treatments were subsequently attacked slightly by a species of stem-rot.
17. Treatment with hot water, as described in this bulletin, has has been found to be beneficial to oats, not only as a remedy for loose smut, but in causing a larger extra increase in the crop.
18. Treatment of oats and corn with sulphide of potassium has been followed by a large extra increase in the crop, not quite so large, however, as in the case of the hot water treatment.
19. The copper sulphate and lime water treatment for oats and wheat does not under ordinary conditions prove beneficial beyond what results from replacing smutted with good seeds.
20. The germicidal effects of potassium sulphide and copper sulphate upon treated seeds seem to be more lasting than those of scalding, formaline or bromine (if the last substance have fungicidal properties.) The less durable effects of the last mentioned substances is evidently due to the fact that solutions loose their strength after a time when exposed to the air.
21. Of the various treatments tried potassium sulphide seems to promise, all things considered, the greatest advantages.
22. Effective remedies for stinking wheat smut are known, and although at present we cannot say definitely that they will be effective against the smut of rice, they are worth trying whenever the smut makes its appearance.
23. Re-infection of treated seeds should be carefully guarded against. This may occur by placing such seed in vessels or places where smutted seeds have been before, or through handling the grain with implements which have been used in smutty grain without subsequent disinfection.

SYNOPSIS.

PART II. A Preliminary Report Upon Treatment for Rice Smut.

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